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Non-volant mammals of the Mestre Álvaro Environmental Protection Area, state of Espírito Santo, southeastern Brazil

Edú B. Guerra,[1,2] Yuri L. R. Leite[1]

1 Laboratório de Mastozoologia e Biogeografia, Departamento de Ciências Biológicas, Universidade Federal do Espírito Santo, Avenida Fernando Ferrari 514, CEP 29075-910, Vitória, ES, Brazil. **2** Current address: Laboratório de Vertebrados, Departamento de Ecologia, Universidade Federal do Rio de Janeiro, Av. Brigadeiro Trompowski s/n, Ilha do Fundão, CEP 21941-902, Rio de Janeiro, RJ, Brazil.
Corresponding author: Edú B. Guerra, edubguerra@gmail.com

Abstract

The Atlantic Forest faces a critical fragmentation process, and is now reduced to just 12.5% of its historical coverage. The state of Espírito Santo is completely inserted within the Atlantic Forest and has a high mammal richness, despite the severe habitat reduction and fragmentation. The Mestre Álvaro Environmental Protection Area is located in the metropolitan region of Vitória and serves as a potential wildlife refuge. We conducted field surveys in this protected area between 2012 and 2013 using live traps and interviews with locals. Herein, we compile a list of 36 species (including 5 threatened species) in the Mestre Álvaro; these mammal species belong to 8 orders, 19 families, and 34 genera. Despite the proximity of Mestre Álvaro to urban areas, published records on the area's fauna and flora are very scarce, and this paper is the first to document the diversity of non-volant mammals in this area.

Key words

Atlantic forest; survey; diversity; species composition.

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Introduction

The Brazilian Atlantic Forest is one of the most important centers of endemism and diversity of the world and a top priority biodiversity hotspot for conservation (Myers et al. 2000). There is only about 12.5% forest cover left of the estimated historical area of 1.3 million km^2 (SOS Mata Atlântica 2015), and most forest fragments are smaller than 50 ha (Ribeiro et al. 2009). The Atlantic Forest reduction and fragmentation occurred mainly due to the exploitation for timber, conversion of land for sugar cane, coffee and soy plantations, pastures, and roads, and urban growth (Dean 1996). The first centers of exploitation and development in Brazilian territory were settled in the Atlantic Forest, where 72% of the Brazilian population lives (SOS Mata Atlântica 2015).

Mammals are highly influenced by environmental disturbances such as fragmentation, and some species are only found in primary forest (Fonseca 1989, Pardini 2004). In addition, species richness and abundance tend to be lower in small and medium-sized patches than in larger patches and continuous forests (Pardini et al. 2005). On the other hand, some species benefit from environmental fragmentation, such as some generalist taxa (Passamani et al. 2000). Most small mammal species have limited dispersal capacity, which makes them vulnerable to environmental fragmentation and therefore

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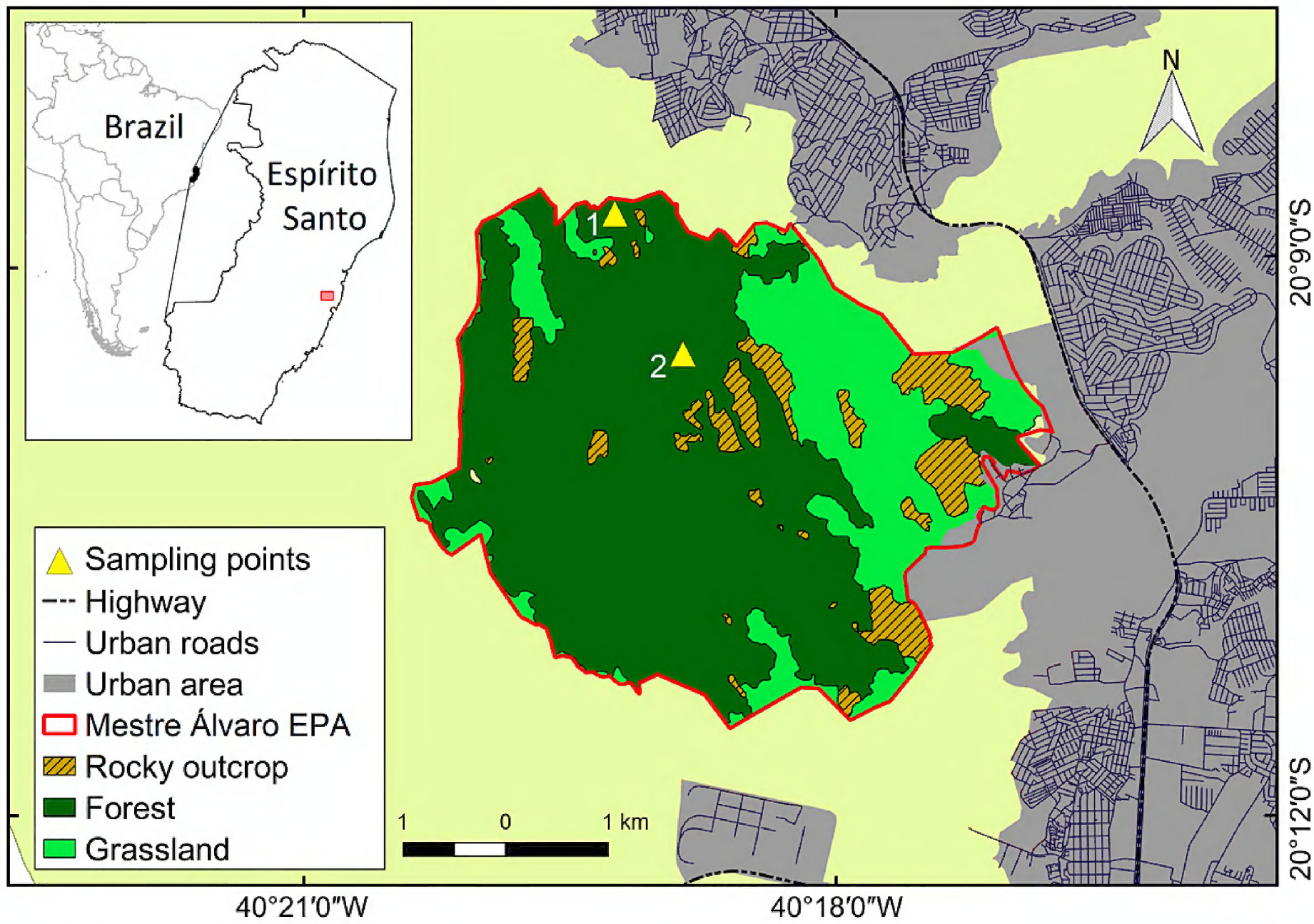

Figure 1. Mestre Álvaro Environmental Protection Area, Serra, Espírito Santo, Brazil. Small mammals sampling points: 1) Clube Capixaba de Golfe, 2) Sítio Pedra D'Água.

good indicators of environmental quality (Pardini and Umetsu 2006).

The state of Espírito Santo is inserted within the Atlantic Forest domain and houses very high mammal richness (Passamani et al. 2000) despite intense forest reduction and fragmentation (Martinelli et al. 2012). Museum records and scientific literature confirm the occurrence of 138 species of mammals in this state (Moreira et al. 2008), which corresponds to almost half of the species that occur in the Brazilian Atlantic Forest as a whole (Paglia et al. 2012). Among the protected remnants of Atlantic Forest in Espírito Santo, Mestre Álvaro Environmental Protection Area (EPA) stands out due to its proximity to urban centers and because of its historical importance as a landmark for navigators entering Vitória Bay since the colonial period (Costa 1995). Published knowledge on the flora and fauna at Mestre Álvaro is quite scarce, despite its potential role as a wildlife refuge (SEMMA 2013). Prior to a bird survey conducted in this area (Lemos 2003), the most recent work documenting the regional fauna was a book by French naturalist August de Saint-Hilaire, who visited the region in the early 19th century (Saint-Hilaire 1833). Inventories are recognized as a simple and important tool for the description of regional faunas, especially in megadiverse countries such as Brazil (Myers et al. 2000, Mittermeier et al. 2005). These surveys are important not only for the wildlife knowledge, but also as a basis for other areas of study, such as ecology, conservation and management strategies (Behera et al. 2005). This study provides the first list of mammals from the Mestre Álvaro EPA, an important protected area of Atlantic Forest in the state of Espírito Santo, southeastern Brazil.

Methods

Study area. Mestre Álvaro is a remnant located in the metropolitan area of Vitória, municipality of Serra (20°10′11″ S, 040°18′45″ W, datum WGS84), state of Espírito Santo, southeastern Brazil (Fig. 1). The remnant is part of the Mestre Álvaro EPA, which covers ca 3470 ha on granitic intrusive bedrock, whose highest peak lies 833 m above sea level (Gimenes 2002). The climate is characterized by rainy season from October to January (Incaper 2017). The region is composed of Atlantic rainforest slopes, featuring dense submontane rainforest, with predominance of xerophytic plants and grasses in some regions, especially near the mountaintop (Leite et al. 2007). Much of the area is covered by grasslands and 1500–2000 ha are still relatively preserved, mainly due to the difficulties in accessing some areas (Lemos 2003).

Species inventory. Non-volant small mammals were captured at 2 sites (Clube Capixaba de Golfe and Sítio Pedra D'Água, Fig. 1) using 2 types of live-traps: Sherman (31 × 8 × 9 cm) and Tomahawk (45 × 17.5 × 15 cm),

baited with pineapple and peanut butter. We established 10–15 trapping stations 10–15 m apart from each other following 6 linear transects (4 at Clube Capixaba de Golfe and 2 at Sítio Pedra D'Água). Each station housed 2 traps (1 of each type), 1 on the ground and the other tied to lianas or tree branches in the understory 1–1.5 m above the ground, whenever possible. Three field campaigns of 5 consecutive nights each were conducted in November 2012, May and August 2013, in a total sampling effort of 832 trap-nights. Given that the goal of our study was to conduct a mammal survey, released animals were not marked, and therefore here we reported the number of captures, not individuals. At least 1 voucher of each species was collected (SISBIO 10070-2) and deposited in the mammal collection at Universidade Federal do Espírito Santo (UFES), in Vitória, Brazil (Appendix).

To reach a satisfactory mammal survey, various sampling techniques should be applied, allowing a better integration of the information provided and, consequently, a comprehensive list of species occurring in a particular area (Voss and Emmons 1996). Thus, semi-structured interviews using snowball-sampling method (Goodman 1961) were conducted with community members who were knowledgeable about the local wildlife. We first asked which mammal species the informant knows from the area. We then asked how the respondent knows that each species occurs there, if the species is common or rare, and how often it has been detected recently, when compared to the last few decades. To confirm these records, species were only included in our list after the respondent provided a detailed description, followed by its recognition in a photographic catalog of 26 species likely to occur in the study area, which was presented at the end of the interview. We conducted 23 interviews and 11 respondents provided images of mammals that were included into the present study as confirmation of the records.

Results

We captured 9 species of mammals: 6 marsupials and 3 rodents, and trapping success was 5.04% (42 captures). The most abundant species was *Didelphis aurita*, followed by *Marmosa paraguayana*. Captures were more frequent on the ground (78.57%) than in the understory (21.43%), where *Gracilinanus microtarsus* was trapped (Table 1).

The interviews indicated 28 mammal species belonging to 19 families, where the orders Carnivora and Rodentia had the highest number of recorded species (10 and 6, respectively). Eighteen species had their records confirmed by photographs given by the respondents or detected by the researchers during field work (Fig. 2). The final list of mammals of Mestre Álvaro EPA is composed by 36 species belonging to 8 orders, 19 families, and 34 genera (Table 2). A couple of *Eira barbara* was photographed only once in the region. *Cerdocyon thous* were occasionally found by locals. The photograph of the *Puma yagouaroundi* was taken in a neighborhood about 3 km from Mestre Álvaro EPA. A *Puma concolor* was photographed on 21 February 2015, after a long time with no sightings of this species in the area. Groups of *Callithrix geoffroyi* and *Sapajus nigritus* were usually sighted by people walking along trails in Mestre Álvaro, and *Alouatta guariba* vocalizations were often heard throughout the forest. Rodents like *Guerlinguetus brasiliensis*, *Chaetomys subspinosus*, and *Coendou* sp. were usually sighted and were mentioned in all interviews. Respondents described 3 armadillo species in the area, *Euphractus sexcinctus*, *Dasypus septemcinctus*, and *Dasypus novemcinctus*, but only the latter was confirmed by photographic records. The maned sloth, *Bradypus torquatus,* was mentioned in all interviews, but only an 8-year old photograph was found, and the respondent has not seen this species since. *Tamandua tetradactyla* were often spotted, and 1 respondent claimed to have seen an individual in the same week of the interview. A juvenile of *Mazama* sp. was photographed in 2016, after a long time with no sights in the area, but respondents mentioned that traces of this species, like feces and footprints, were often found. All respondents mentioned the presence of a small wildcat species of the genus *Leopardus*, but we were unable to identify it to species level due to the

Table 1. Richness and abundance of non—volant small mammals sampled in Mestre Álvaro Environmental Protection Area, Espírito Santo, Brazil in 2012—2013.

Order/family	Species	Number of individuals		Relative abundance (%)
		Ground	Understory	
Didelphimorphia				
Didelphidae	*Didelphis aurita* (Wied-Neuwied, 1826)	10	2	29
	Marmosa paraguayana (Tate, 1931)	6	6	26
	Marmosops incanus (Lund, 1840)	4	—	10
	Philander frenatus (Olfers, 1818)	3	—	7
	Gracilinanus microtarsus (Wagner, 1842)	—	1	2
	Monodelphis americana (Müller, 1776)	1	—	2
Rodentia				
Cricetidae	*Akodon cursor* (Winge, 1887)	1	—	2
	Nectomys squamipes (Brants, 1827)	1	—	2
Echimyidae	*Trinomys paratus* (Moojen, 1948)	8	—	19
Total		33	9	100

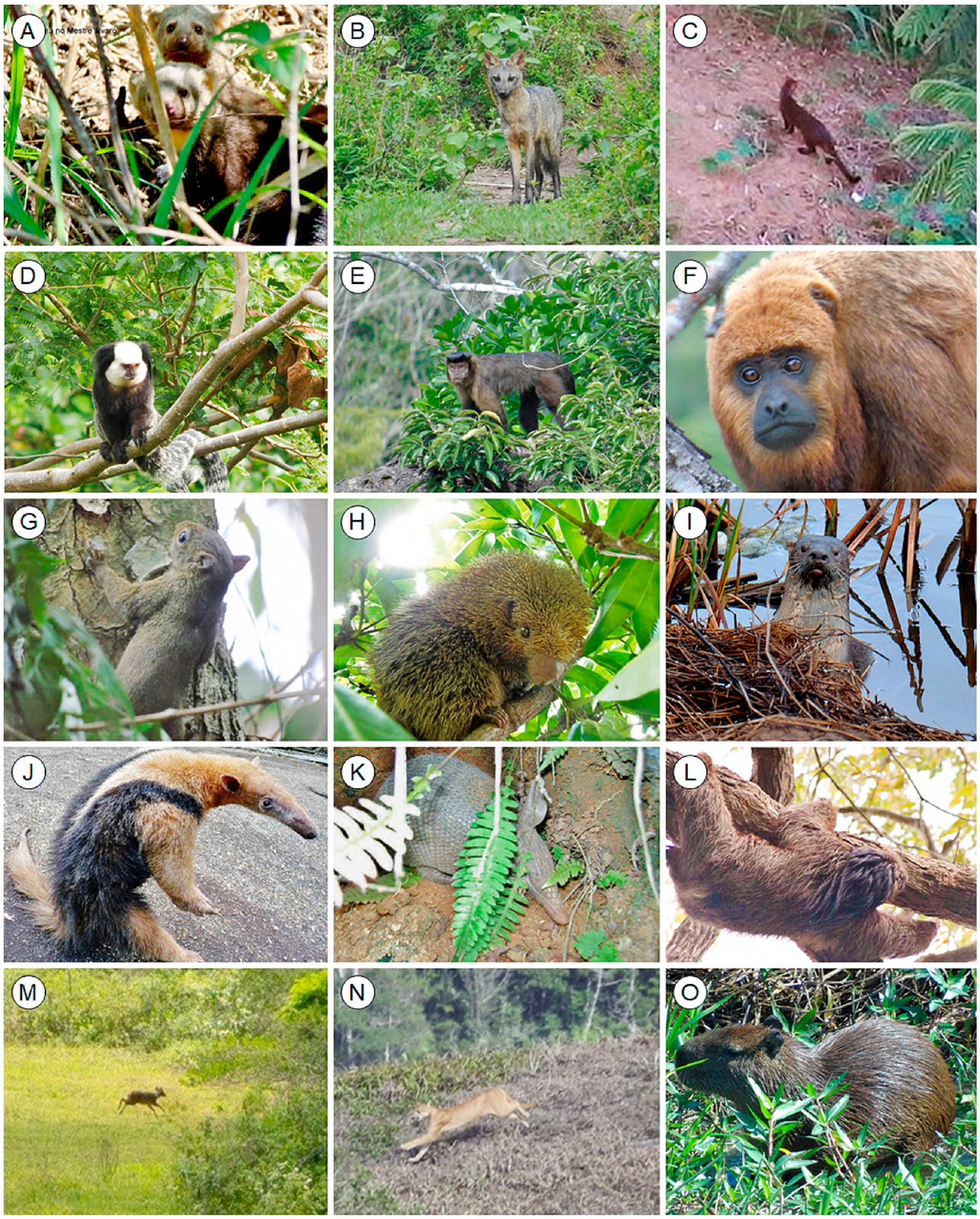

Figure 2. Mammals from Mestre Álvaro Environmental Protection Area, Serra, Espírito Santo, Brazil. **A.** *Eira barbara*. **B.** *Cerdocyon thous*. **C.** *Puma yagouaroundi*. **D.** *Callithrix geoffroyi*. **E.** *Sapajus nigritus*. **F.** *Alouatta guariba*. **G.** *Guerlinguetus brasiliensis*. **H.** *Chaetomys subspinosus*. **I.** *Lontra longicaudis*. **J.** *Tamandua tetradactyla*. **K.** *Dasypus novemcinctus*. **L.** *Bradypus torquatus*. **M.** *Mazama* sp. **N.** *Puma concolor*. **O.** *Hydrochoerus hydrochaeris*. Photographs by Vanderson Neves (A, J), Márcio Miranda (B, E, H, K, O), Filipe Ramos (C), Orlando Magnago (D), Júnior Nass (F, G), Hilton Monteiro (I), Wallace Cardoso (L) and Rafael Apelfeler (M), Maycon Wesley (N).

similarity of pelage patterns. *Hydrochoerus hydrochaeris* and *Lontra longicaudis* were photographed in a flooded area, where some respondents highlighted the presence of those species. Terrestrial rodents like *Dasyprocta* sp. and *Cuniculus paca* were commonly seek by hunters, according to respondents, and have been increasingly difficult to find over the years. In addition to wild species, we recorded 3 domestic mammals in the area: dogs (*Canis lupus familiaris*), cats (*Felis silvestris catus*), and cattle (*Bos taurus*).

Table 2. Mammal species of Mestre Álvaro Environmental Protection Area with their respective type of record and conservation status. Type of record represented by In = Interview, Ph = Photograph, Vs = Visual, Vc = Vocalization, Vo = Voucher. Conservation status follows the IUCN Red List of Threatened Species (IUCN 2017) and ICMBio (2014) within parentheses, depicting global and national conservation status respectively: LC = Least Concern, NT = Near Threatened, VU = Vulnerable, CR = Critically Endangered.

Order/family	Species	Type of record	Conservation status
Didelphimorphia			
Didelphidae	*Caluromys philander* (Linnaeus, 1758)	In, Ph	LC
	Didelphis aurita (Wied-Neuwied, 1826)	Vo, In, Ph	LC
	Gracilinanus microtarsus (Wagner, 1842)	Vo	LC
	Marmosa paraguayana (Tate, 1931)	Vo	LC
	Marmosops incanus (Lund, 1840)	Vo	LC
	Monodelphis americana (Müller, 1776)	Vo	LC
	Philander frenatus (Olfers, 1818)	Vo	LC
Pilosa			
Bradypodidae	*Bradypus torquatus* Illiger, 1811	In, Ph	VU (VU)
Myrmecophagidae	*Tamandua tetradactyla* (Linnaeus, 1758)	In, Ph	LC
Cingulata			
Dasypodidae	*Dasypus novemcinctus* (Linnaeus, 1758)	In, Ph	LC
	Dasypus septemcinctus (Linnaeus, 1758)	In	LC
	Euphractus sexcinctus (Linnaeus, 1758)	In	LC
Carnivora			
Canidae	*Cerdocyon thous* (Linnaeus, 1766)	In, Ph	LC
Felidae	Leopardus sp.	In	—
	Puma concolor (Linnaeus, 1771)	In, Ph	LC (VU)
	Puma yagouaroundi (Geoffroy, 1803)	In, Ph	LC (VU)
Mustelidae	*Eira barbara* (Linnaeus, 1758)	In, Ph	LC
	Lontra longicaudis (Olfers, 1818)	In, Ph	NT
Procyonidae	*Conepatus semistriatus* (Boddaert, 1785)	In	LC
	Nasua nasua (Linnaeus, 1766)	In	LC
	Potos flavus (Schreber, 1774)	In	LC
	Procyon cancrivorus (Cuvier, 1798)	In	LC
Cetartiodactyla			
Cervidae	*Mazama* sp.	In, Ph	—
Lagomorpha			
Leporidae	*Sylvilagus brasiliensis* (Linnaeus, 1758)	In	LC
Primates			
Cebidae	*Callithrix geoffroyi* (Humboldt, 1812)	In, Ph, Vs, Vc	LC
	Sapajus nigritus (Goldfuss, 1809)	In, Ph	NT
Atelidae	*Alouatta guariba* (Humboldt, 1812)	In, Ph, Vc	CR (CR)
RODENTIA			
Caviidae	*Hydrochoerus hydrochaeris* (Linnaeus, 1766)	In, Ph	LC
Cricetidae	*Akodon cursor* (Winge, 1887)	Vo	LC
	Nectomys squamipes (Brants, 1827)	Vo	LC
Cuniculidae	*Cuniculus paca* (Linnaeus, 1766)	In	LC
Dasyproctidae	*Dasyprocta* sp.	In	—
Echimyidae	*Trinomys paratus* (Moojen, 1948)	Vo	DD
Erethizontidae	*Chaetomys subspinosus* (Olfers, 1818)	In, Ph	VU (VU)
	Coendou sp.	In, Ph	—
Sciuridae	*Guerlinguetus brasiliensis* (Thomas, 1901)	In, Ph	—

Discussion

The higher richness and abundance of marsupials in relation to rodents has been documented in other studies in the Atlantic Forest of the state of Espírito Santo (e.g., Santos et al. 2004). Secondary forest habitats may favor marsupials (Stallings 1989, Dalmaschio and Passamani 2003), while the abundance of rodents is related to the most pristine areas of the Atlantic Forest (Bergallo 1994). The Mestre Álvaro EPA is located in a metropolitan area with substantial human pressure, where there are extensive agricultural areas, livestock, and rock extraction (Nardoto 2013). The remaining forest fragments consist of secondary forests, which are favoring marsupials, such as *Didelphis aurita* and *Marmosa paraguayana*, which comprise 29% and 26% of the captures, respectively. The dominance of *D. aurita* might be related to 2 factors. First, the generalist habits, characterized by the plasticity in the vertical use of forest strata (Grelle 2003) and an omnivorous diet (Leite et al. 1996, Freitas et al. 1997, Carvalho et al. 2005); and second, the fact that the area consists mostly of secondary forest, which normally houses communities dominated by generalist species (Laurance 2007, Gardner et al. 2007), given that a typical result of environmental

degradation is the loss of species and an increase in dominance (Magurran 2004). *Didelphis aurita* is the largest species among didelphid marsupials (ca 1 kg, Eisenberg and Redford 1999), and it has the largest home range (122 ha on average, Pires et al. 2002), which allows them to use a variety of resources (Carvalho et al. 2005). *Didelphis aurita* is also widely distributed, occurring throughout the Atlantic Forest (Emmons and Feer 1997). Due to its large home range and ability to perform long distances movements, this species sometimes extrapolates the limits of its natural habitat, occupying areas inhabited by humans (Pardini 2004). These ecological attributes of *D. aurita* may explain its resistance to habitat fragmentation, as the species is present even in small forest fragments. Higher densities of *D. aurita* do not necessarily indicate habitat degradation, since this species is also abundant in well-conserved areas (Fonseca 1989, Stallings et al. 1991, Moura et al. 2005), although it tends to dominate mammal community in small to medium-sized fragments (Fonseca and Robinson 1990).

The second commonest species, *M. paraguayana,* is a widely distributed Neotropical marsupial (Charles-Dominique et al. 1981, Gardner and Creighton 2008). It is mainly arboreal, but eventually descends to the ground in search of food (Emmons and Feer 1997, Goulart et al. 2006). It is insectivorous–omnivorous, eating primarily fruits and arthropods (Rossi et al. 2006). Despite its arboreal habits, this species significantly explored the terrestrial strata in this study. This may be due to the forest structure in a heterogeneous landscape, where a discontinuous canopy and few vines connecting the understory layer hamper arboreal movements (Wells et al. 2006).

The dominance of captures on the ground (78.57%) reflects the terrestrial habits of most species recorded, such as *Akodon cursor* (Prevedello et al. 2008) and *Trinomys paratus* (Attias et al. 2009). *Monodelphis americana* is semi-fossorial and rarely captured in conventional traps (Pine and Handley 2007). *Didelphis aurita* and *Philander frenatus* are scansorial, with preference for the terrestrial stratum (Grelle 2003, Vieira and Monteiro-Filho 2003). *Marmosa paraguayana* and *Marmosops incanus* are preferably arboreal, but often exploit the ground in search of food (Goulart et al. 2006, Loretto and Vieira 2008). *Nectomys squamipes* is semi-aquatic (Ernest and Mares 1986), and was captured on the ground, next to a watercourse. Three species were captured in the understory: *D. aurita*, *M. paraguayana*, and *Gracilinanus microtarsus*, but only the latter is arboreal (Abreu and Oliveira 2014).

The capture success (5.04%) obtained is higher to those found in other studies conducted in nearby areas such as Duas Bocas Biological Reserve (3.59%, see Tonini et al. 2010) and Fonte Grande State Park (1.47%, in Santos et al. 2004, to 1.90% in Caldara Jr and Leite 2007), in the state of Espírito Santo. Our sampling effort (832 trap-nights) was much lower than the others (3456 trap-nights at Fonte Grande and 7920 trap-nights at Duas Bocas), which may represent a bias in our list of species. In addition, we sampled a relatively small area in the northern portion covering less than 10% of the Mestre Álvaro EPA. Therefore our list is certainly far from complete, but it is the first published record of the mammal fauna of this important Atlantic Forest remnant.

Although camera-traps are the most effective method for detecting medium-sized and large mammals (Galvez 2016), interviews are promising due to their low cost and short-term data acquisition (Fonseca 2001, Turvey et al. 2015). This technique was indeed effective in our study, considering that more than half of the species reported through interviews were also confirmed by photographs provided by the respondents. Since there is a steep growth rate in the number of people owning photographic devices (Pew Research Center 2016), photographs allied to interviews are powerful tools for validating the occurrence of medium-sized and large mammal species. This is especially relevant in protected areas that are close to urban centers and open to the public, such as Mestre Álvaro EPA.

According to the IUCN Red List of Threatened Species (IUCN 2017), the clear majority of species recorded in the Mestre Álvaro EPA are classified as Least Concern, which is expected given its proximity to urban centers and the long history of human occupation. *Puma concolor* and *Puma yagouaroundi* are both classified as Vulnerable in the ICMBio list, but as Least Concern on the IUCN list due their wide distribution compared to other wild cats. *Lontra longicaudis* and *Sapajus nigritus* are not mentioned on the Brazilian list (ICMBio 2014) but both are Near Threatened on the IUCN Red List (IUCN 2017).

Telemetry studies suggest that pumas (*P. concolor*) have extensive home ranges in various biomes (Paula et al. 2015) and have been confirmed in 2 protected areas nearby (Duas Bocas Biological Reserve and Santa Lúcia Ecological Station). It is therefore possible that individuals of *P. concolor* are moving among these fragments.

Large and medium-sized mammals are affected by fragmentation and habitat alteration caused by human occupation (Rodrigues et al. 2002, Trolle et al. 2007), which are the major threats to this group along with hunting pressure, although this activity has been illegal in the country for over 45 years (Costa et al. 2005). The hunting pressure in Mestre Álvaro EPA dates back to the early 19th century, when Saint-Hilaire (1833) recorded "lots of these trapdoors called *mundéus*, it is customary to get quadrupeds". Even today, we find traps in areas of dense forest and near armadillo holes at Mestre Álvaro EPA (Fig. 3). Domestic species roam the Mestre Álvaro due to the presence of rural properties (Nardoto 2013). Exotic and domestic species in protected areas directly or indirectly affect wild species, and may even lead them to extinction (Primack 1998). Populations of *Canis lupus familiaris* represent potential reservoirs of diseases and parasites, and are potential competitors with other medium-sized mammals, including some big cats and smaller carnivores such as *Cerdocyon thous* (Srbek-Araujo and Chiarello 2008).

In contrast to the factors negatively affecting mammals in this area, Mestre Álvaro EPA presents a fair diversity

Figure 3. Hunter traps, called "loca" and "canhãozinho", found in Mestre Álvaro Environmental Protection Area. Photos by Jazz Magnago.

of habitats, such as areas of vegetation associated with watercourses, wetlands, woodlands, rocky outcrops, among others (Nardoto et al. 2013). This diversity of environments can provide food resources and shelter for the establishment of a well-structured community of mammals (August 1983), if conservation measures are in place (Pinotti et al. 2012).

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Authors' Contributions

EBG collected and analyzed the data, YLRL identified the species, EBG and YLRL wrote the text.

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Appendix

Institutional catalog number of the vouchers collected during this study and housed in the mammal collection at Universidade Federal do Espírito Santo (UFES-MAM), Vitória, Brazil

Order Didelphimorphia:

Didelphis aurita (2367, 2368, 2525), *Gracilinanus microtarsus* (2527), *Marmosa paraguayana* (2369, 2370, 2522, 2523, 2524, 2530, 2535, 2539), *Marmosops incanus* (2529, 2536, 2538, 2542), *Monodelphis americana* (2531), *Philander frenatus* (2526, 2533).

Order Rodentia:

Akodon cursor (2371), *Nectomys squamipes* (2372), *Trinomys paratus* (2528, 2532, 2534, 2537, 2540, 2541).